Updates on Run12 π^0 – jet A_{LL}

Yaping Wang (CCNU)
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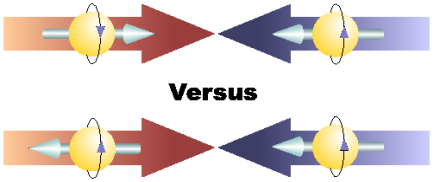


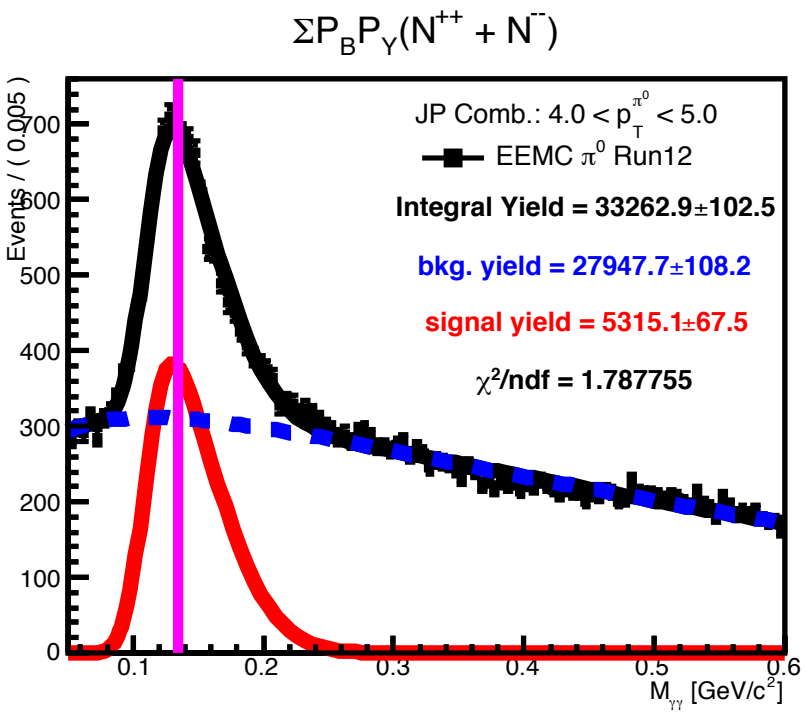
Outline

- Technical details of analysis method
- Comments from last SPIN PWG meeting (August 8, 2016)
- Checks responded to the comments
- Updates of analysis results
- Summary and outlook

Asymmetry Analysis -- variable re-binning

```
const Double_t mPi0PTbins_rebin[8]={ 4.0, 5.0, 6.0, 8.0, 10.0, 12.0, 16.0, 36.0};

const Double_t mJetPTbins_rebin[8] = {7.1, 9.9, 13.8, 19.2, 26.8, 37.3, 51.9, 100.0};

const Double_t mPi0JetMassbins_rebin[7] = {17.0, 24.0, 35.0, 50.0, 72.0, 100.0, 200.0};

const Double_t mX1bins_rebin[6] = { 0.07, 0.10, 0.15, 0.23, 0.35, 0.53};

const Double_t mX2bins_rebin[6] = { 0.01, 0.02, 0.04, 0.06, 0.12, 0.24};
```

Asymmetry Analysis – signal yield estimation method update



The invariant mass spectrum (weighted by relative luminosities and beam polarizations), are fitted to estimate signal yield for each kinematic variable bin, respectively.

$$sig(x):\ k \times e^{\frac{-(x-\mu)^2}{2\sigma^2}} \times [1 + \mathrm{Erf}(\frac{a(x-\mu)}{\sqrt{2}\sigma})]$$

$$bkg(x):\ A \times x^B \times e^{Cx}$$

$$model(x) = \frac{n_{sig}}{n_{sig} + n_{bkg}} * sig(x) + \frac{n_{bkg}}{n_{sig} + n_{bkg}} * bkg(x)$$

$$n_{raw} * model(x) = n_{sig} * sig(x) + n_{bkg} * bkg(x)$$

- The **raw yield** (n_{raw})of π^0-jet are well fitted by *model(x)*, in which the signal shape was described by **skewed Gaussian function** *sig(x)*, and background shape was fitted by **Gamma function** *bkg(x)*;
- The shapes of *sig(x)* and *bkg(x)* were determined by fitting the spectrum summed over spin states.
- ***Signal yield*** **(n_{sig})** and **background yield (n_{bkg})** are estimated by fitting over [0.05, 0.6] GeV/c^2 with the fixed *sig(x)* and *bkg(x)* shapes, according

$$n_{raw} * model(x) = n_{sig} * sig(x) + n_{bkg} * bkg(x)$$

- Signal (background) asymmetries, A_{LL}^S (A_{LL}^B), are calculated by the fitted normalization n_{sig} (n_{bkg}).

Asymmetry Analysis – comments from last SPIN PWG meeting

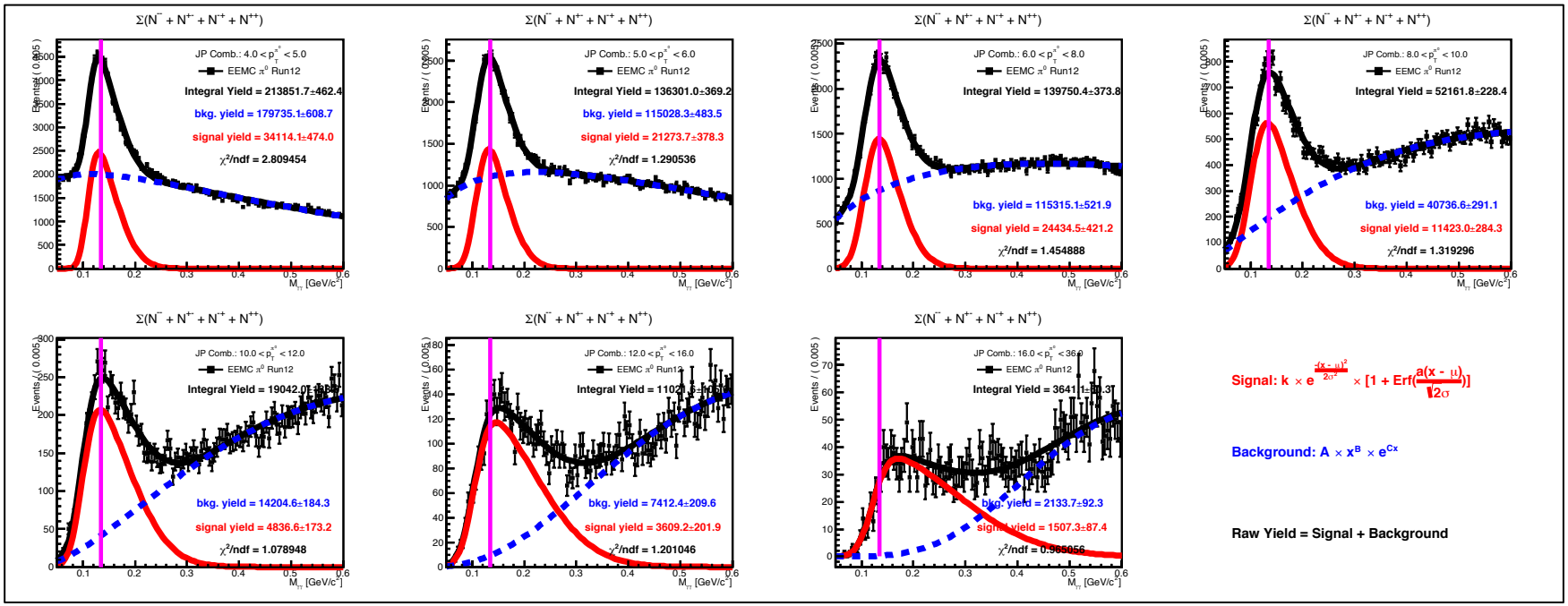
- Check the shape of background is truly independent of spin states (Scott). ---- done!
- We need a way to propagate the uncertainty in the signal and background *shapes* into the yield uncertainties, which (presumably) already contain the uncertainties from the signal function amplitudes. ---- done!
- The background false asymmetries, A_L(Y/B) and A_LL(US), look pretty large. It's not yet clear what is driving this. We discussed the following possibilities:
  - Rapidity dependence (seems unlikely) ---- not yet
  - Single-beam backgrounds ---- not yet
  - Double-check that the run list and relative luminosity values are optimal. It would make sense if the run list was a subset of the inclusive/di-jet A_LL list, but probably not a superset. Make sure that the filled bunches Zilong required are in fact there. ----done!
- It would be nice to have updated theory curves. NNPDF1.1 should be available through LHAPDF, and Carl will send the new DSSV code to Zhenyu. ---- later

Asymmetry Analysis – check the background shape dependence on spin states

Proposed by Scott:

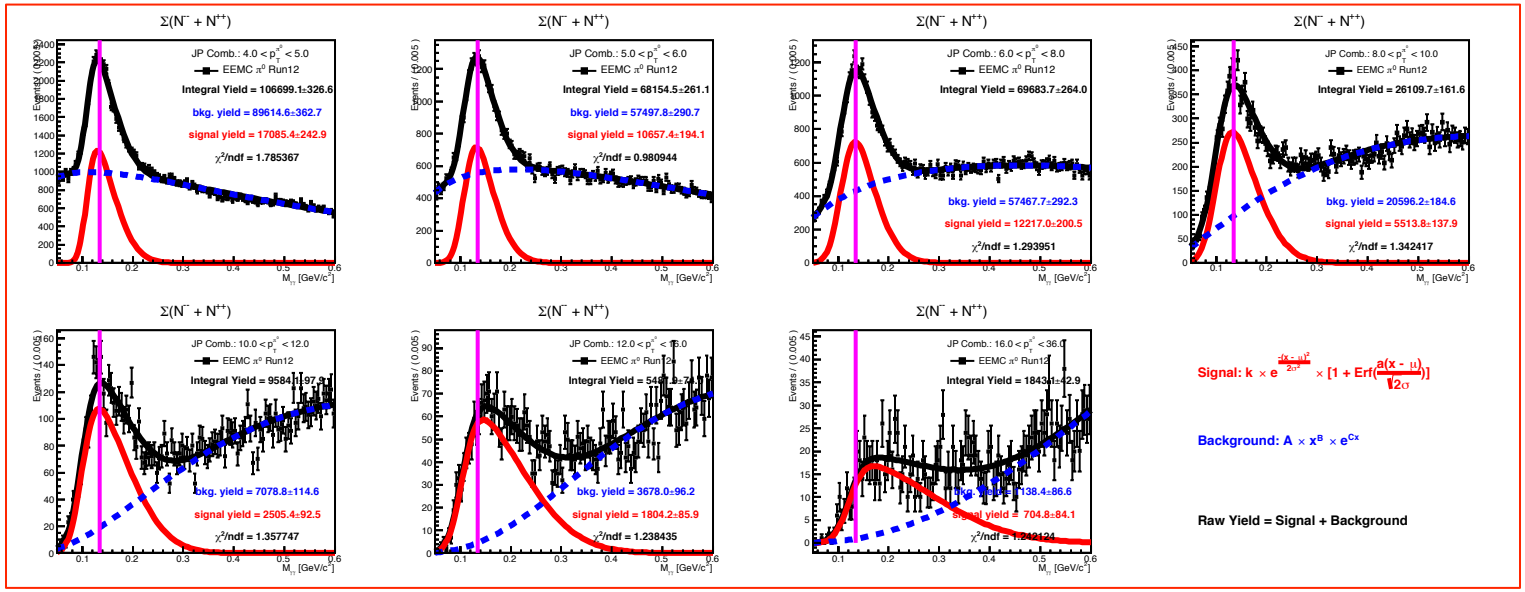
- A quick way to test this would be to fit the spin-summed spectrum (as we currently do), then fit each of the two spin states (combine N^{++} and N^{--}, and also N^{+-} with N^{-+}) holding the pion peak parameters fixed, but let the background shape vary.
- If the parameters for the background shapes are statistically quite close to each other, then you can argue that the 'jettiness' of the background is not a problem for this analysis method.

$$N^{++} + N^{--} + N^{+-} + N^{-+}$$

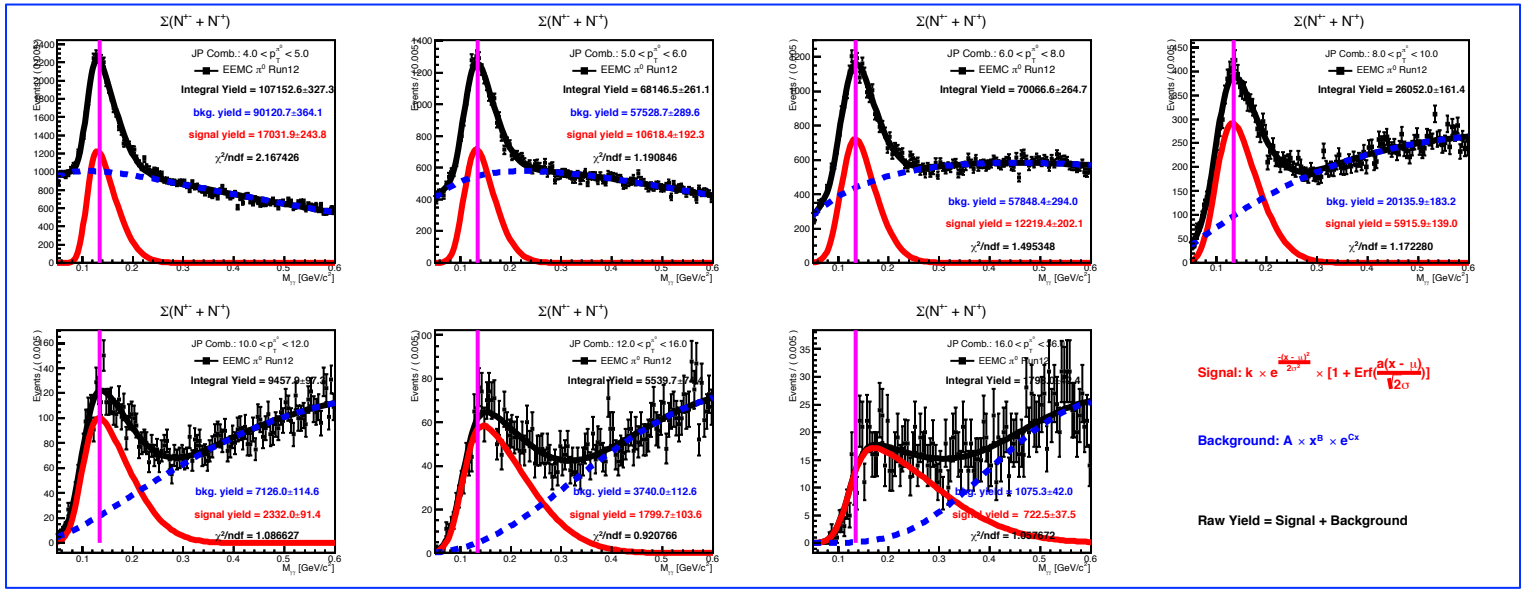


Asymmetry Analysis – check the background shape dependence on spin states

$N^{++} + N^{--}$



$N^{+-} + N^{-+}$



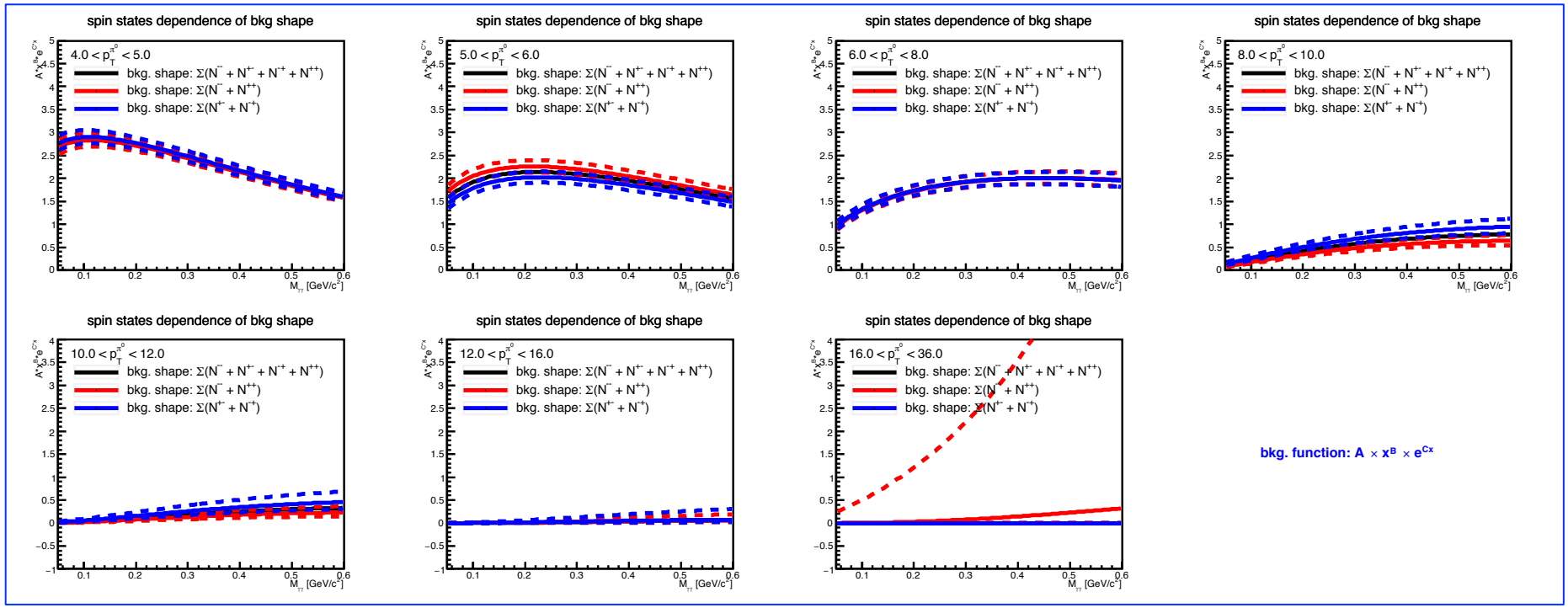
Asymmetry Analysis – check the background shape dependence on spin states

Shape of background (Gamma function: $A \times x^{B} \times e^{Cx}$):

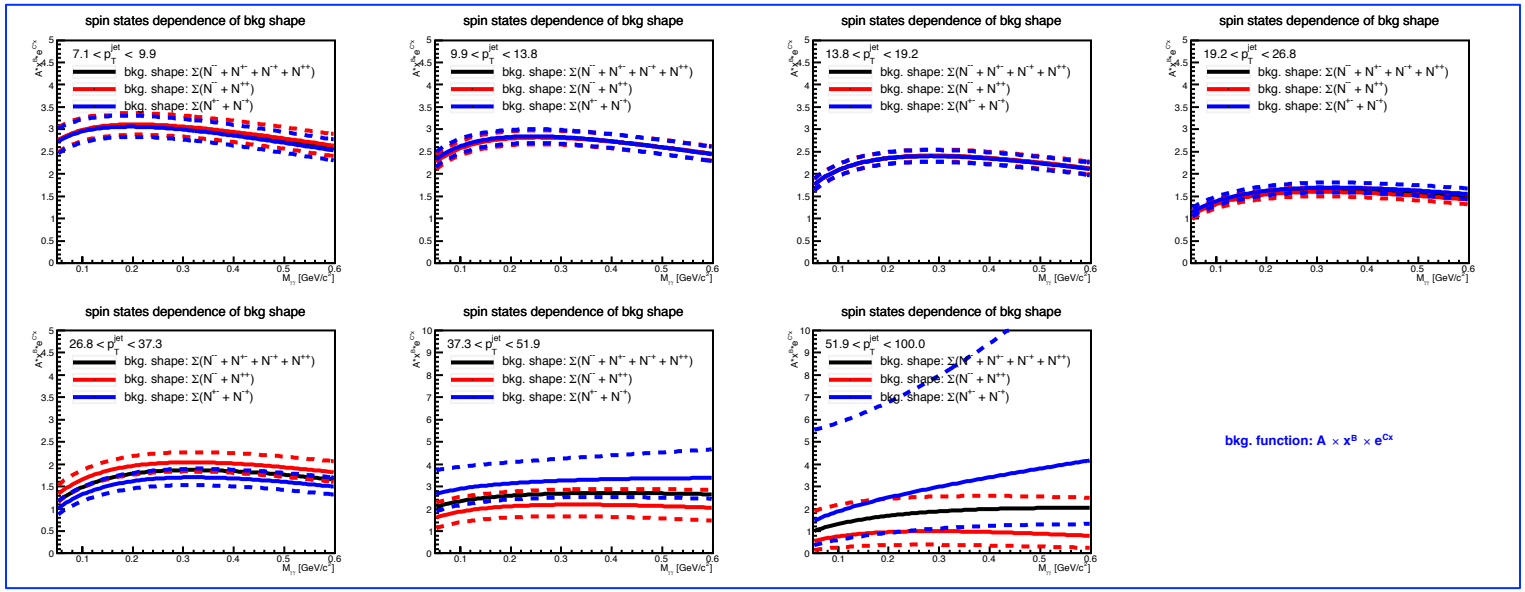
- Black solid line: mean values (A, B, C) from all spin-summed spectrum
- Red solid line: mean values (A, B, C) from summed spectrum of spin state 5 and 10

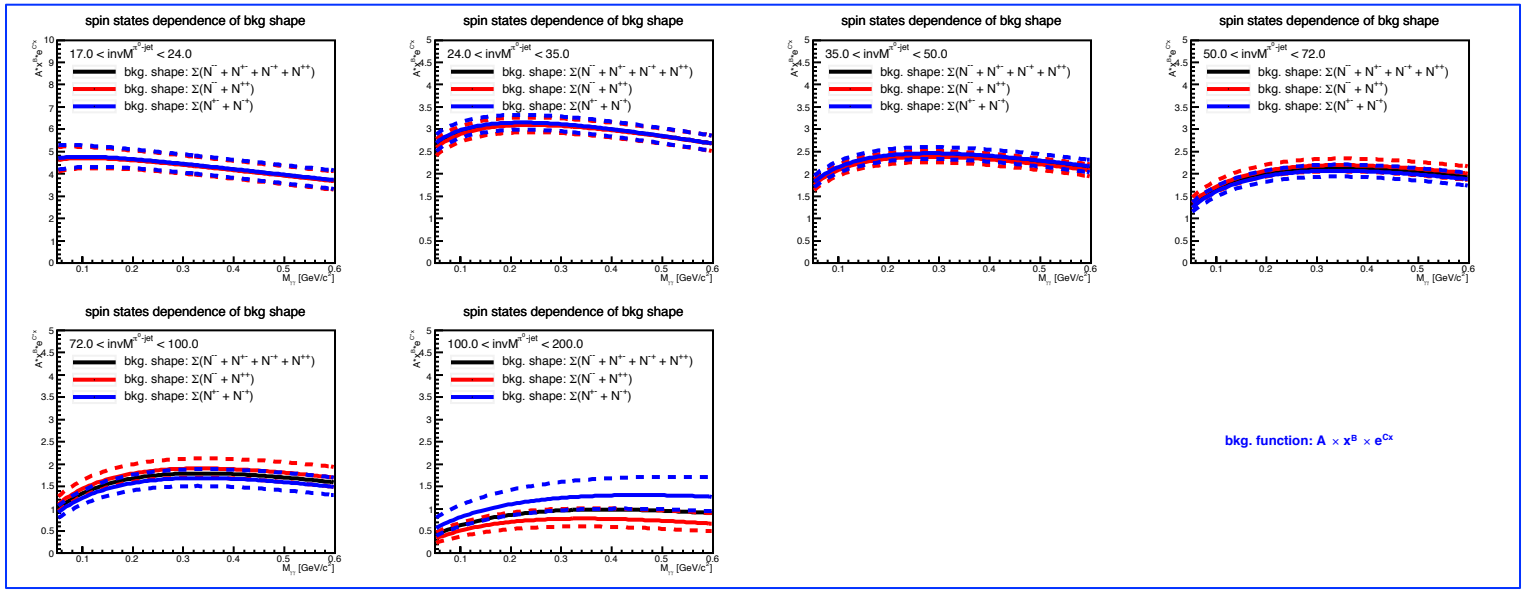
  Red dash line: one sigma standard deviation of the mean values (A, B, C) .
- Blue solid line: mean values (A, B, C) from summed spectrum of spin state 6 and 9

  Blue dash line: one sigma standard deviation of the mean values (A, B, C).

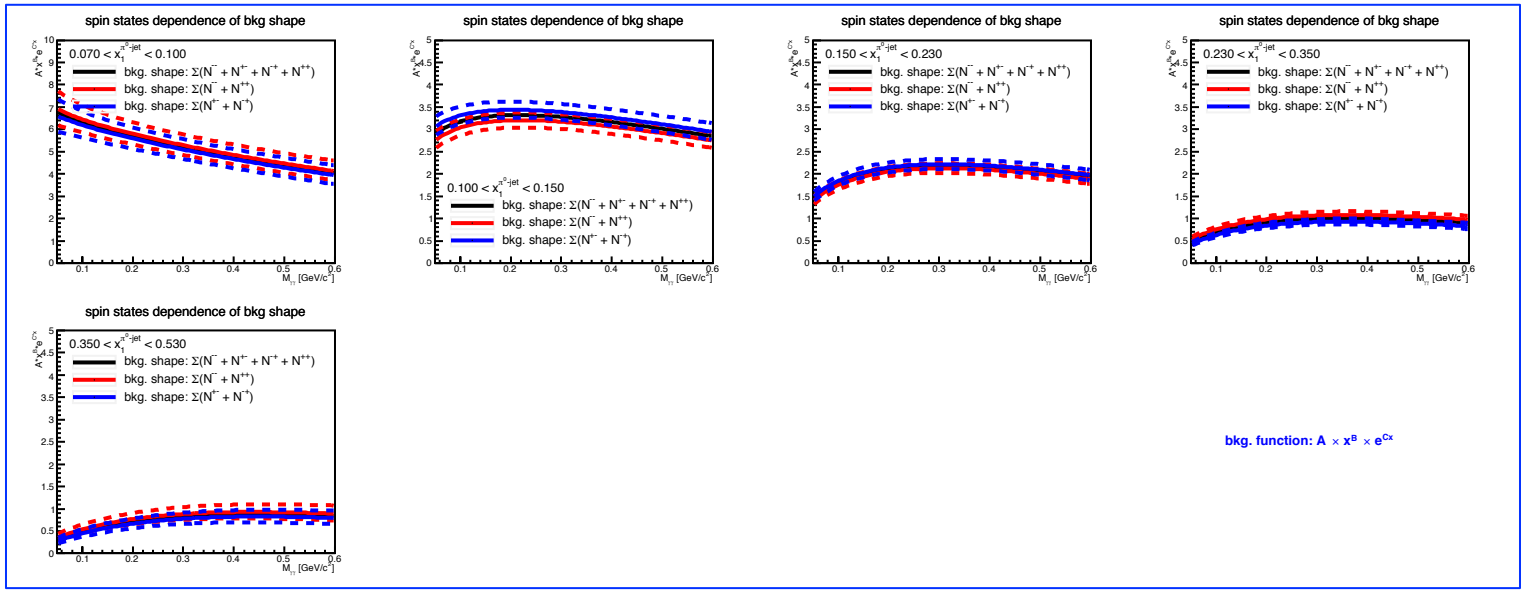


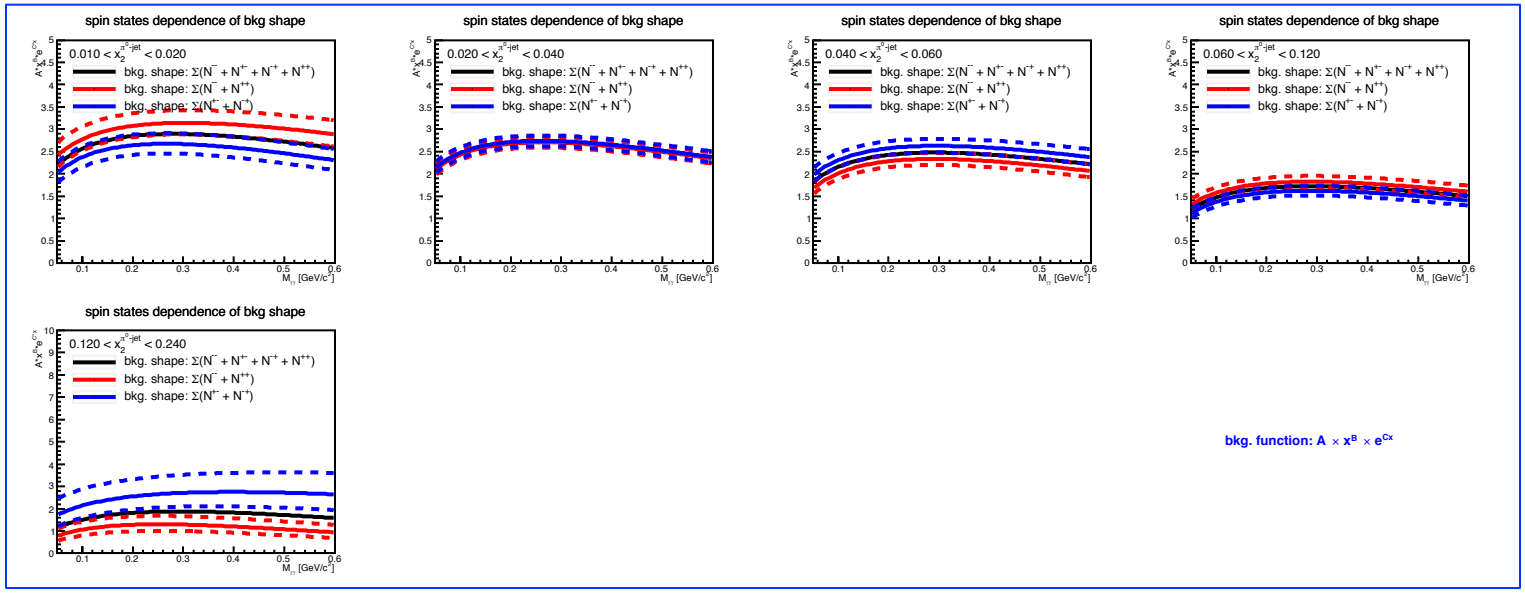
Asymmetry Analysis – check the background shape dependence on spin states





Asymmetry Analysis – check the background shape dependence on spin states





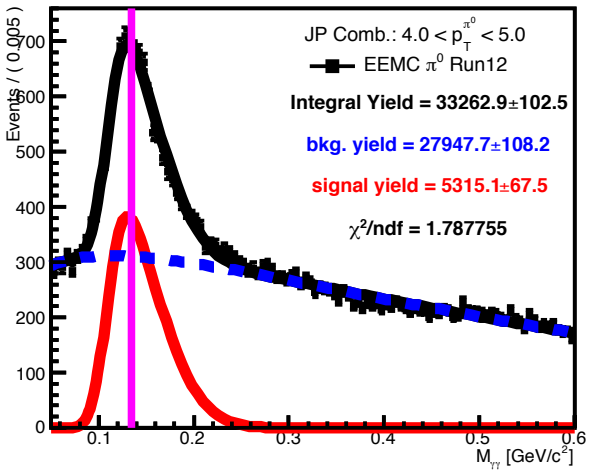
Asymmetry Analysis – check the background shape dependence on spin states

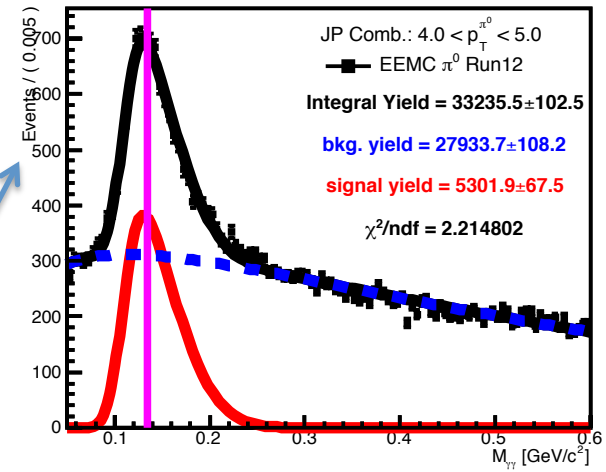
Conclusion:

- A quick test was done for the background shape dependence on spin states;
- The check results show the background shape is independent of spin states within one sigma deviation.

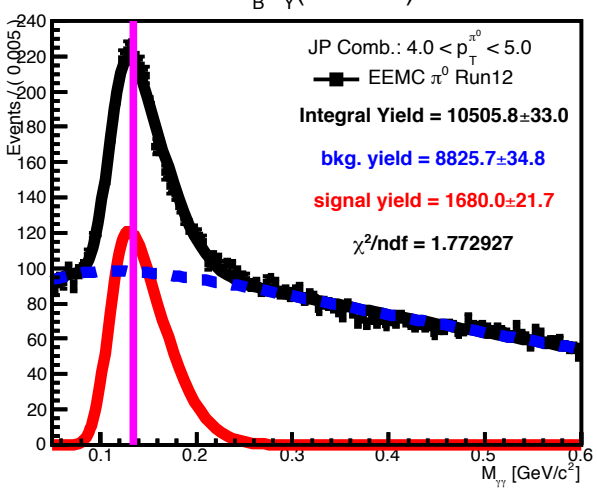
Asymmetry Analysis – correlations check for A_{LL} calculation

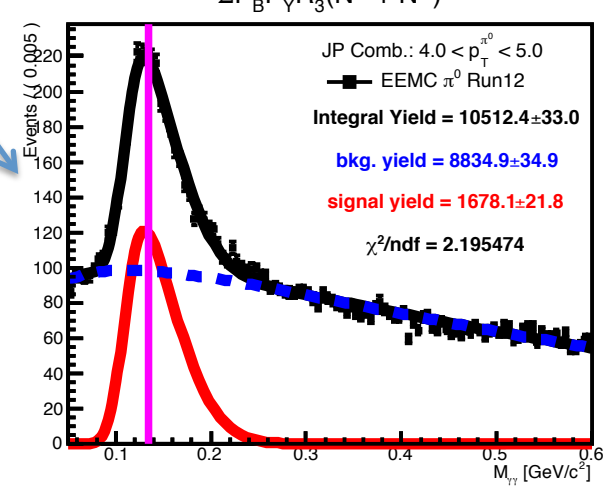
- Using the fixed signal and background shapes, *sig(x)* and *bkg(x)*, then only fit the signal and background normalization (n_{sig} and n_{bkg}) for each bin (taking the A_{LL} in π^0 p_T bin [4.0,5.0] for an example).





$$A_{LL} = \frac{\sum P_Y P_B[(N^{++}+N^{--}) - R_3(N^{+-}+N^{-+})]}{\sum P_Y^2 P_B^2[(N^{++}+N^{--}) + R_3(N^{+-}+N^{-+})]}$$



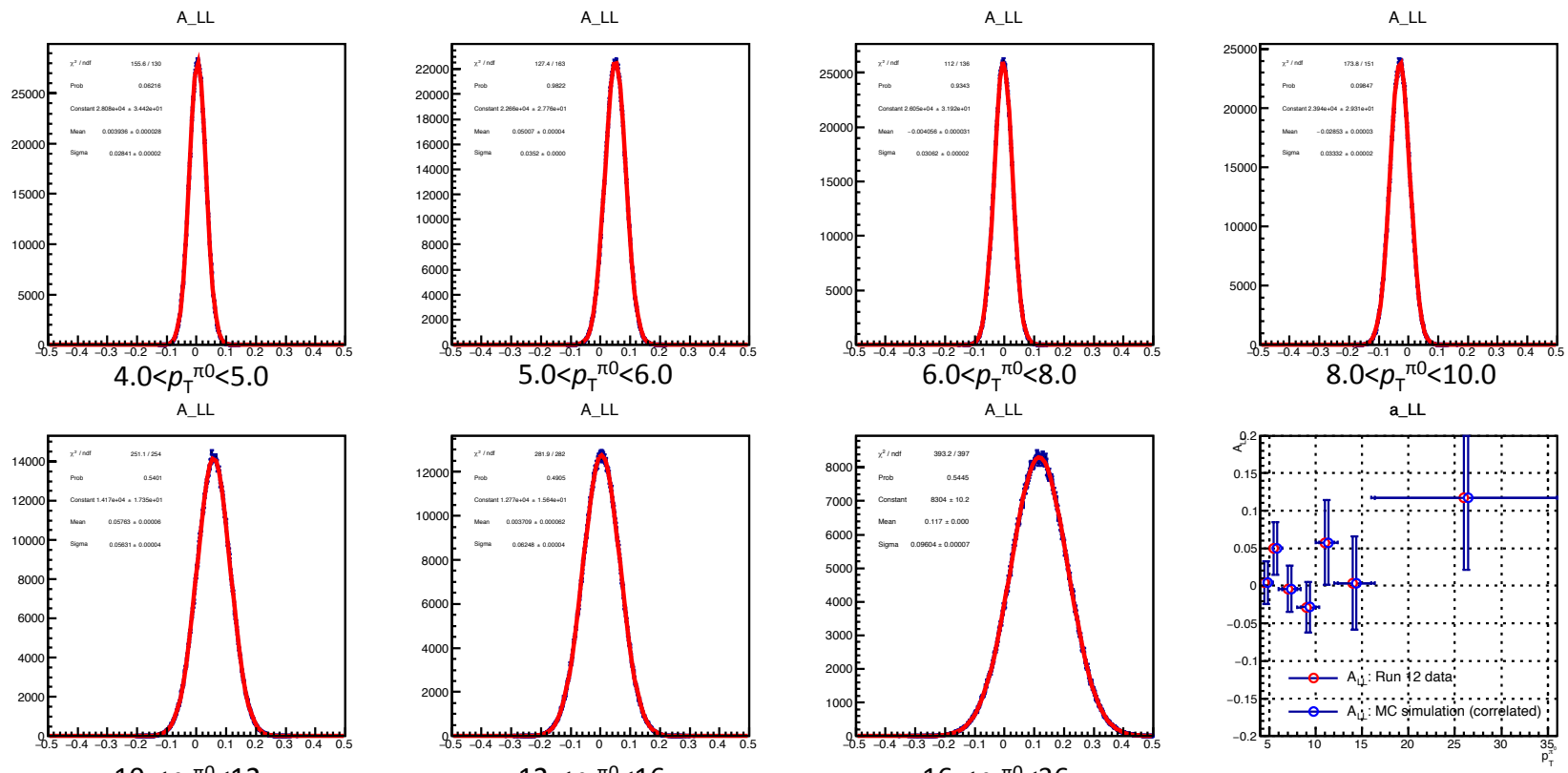


Note: correlations between numerator and denominator was not considered yet, and will be take into account (could reduce the statistical uncertainties).

Asymmetry Analysis – correlations check for A_{LL} calculation

```
for(int j=0; j<MAX; j++) {
{
   double nsig_num1 = r.Gaus(nsig_num1_pi0PT[i], nsigErr_num1_pi0PT[i]);
   double factor1       = nsig_num1 / nsig_num1_pi0PT[i];
   double nsig_den1   = nsig_den1_pi0PT[i] * factor1;

   double nsig_num2 = r.Gaus(nsig_num2_pi0PT[i], nsigErr_num2_pi0PT[i]);
   double factor2 = nsig_num2 / nsig_num2_pi0PT[i];
   double nsig_den2 = nsig_den2_pi0PT[i] * factor2;

   double aLL = (nsig_num1 - nsig_num2) / (nsig_den1 + nsig_den2);
   hALL[i]->Fill(aLL);
}
```

- A MC test was done for the correlations check;
- The check shows that the correlation effects have no clear impacts on the ALL calculation (no significant difference was found between data and MC simulation taking into account correlations).



$4.0<p_T^{\pi0}<5.0$ $5.0<p_T^{\pi0}<6.0$ $6.0<p_T^{\pi0}<8.0$ $8.0<p_T^{\pi0}<10.0$

$10.<p_T^{\pi0}<12.$ $12.<p_T^{\pi0}<16.$ $16.<p_T^{\pi0}<36.$

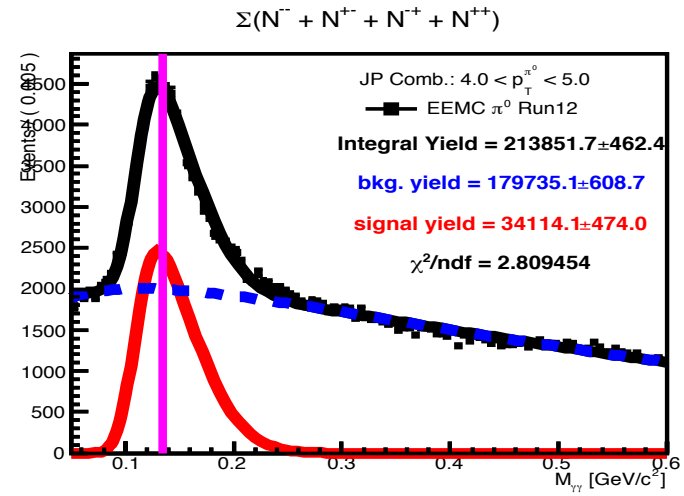
Asymmetry Analysis – uncertainty propagation from the sig and bkg shapes

Find a way to propagate the uncertainty in the signal and background *shapes* into the yield uncertainties, which (presumably) already contain the uncertainties from the signal function amplitudes.

$$sig(x):\ k \times e^{\frac{-(x-\mu)^2}{2\sigma^2}} \times [1 + \mathrm{Erf}(\frac{a(x-\mu)}{\sqrt{2}\sigma})]$$

$$bkg(x):\ A \times x^B \times e^{Cx}$$

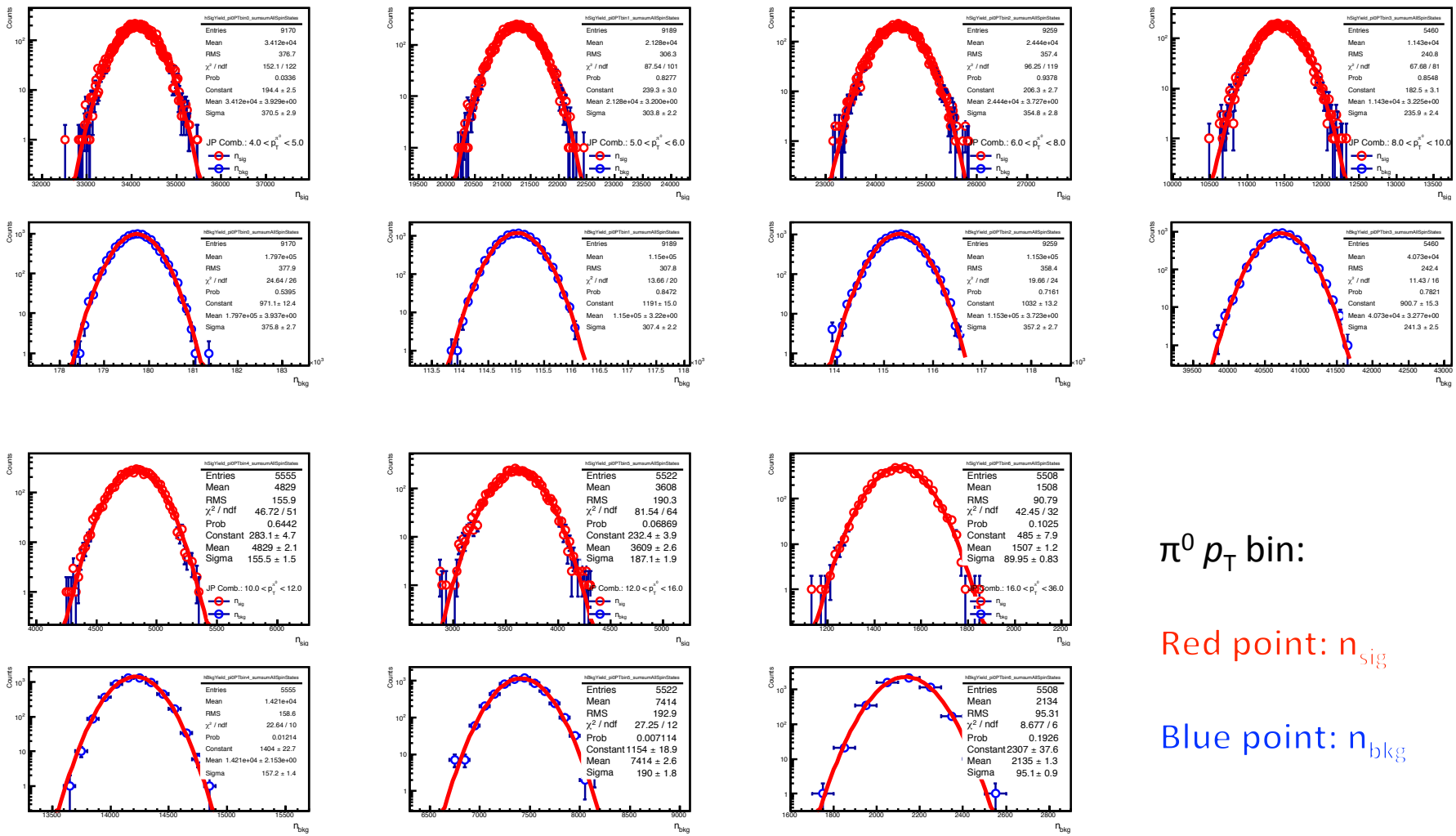
$$model(x) = \frac{n_{sig}}{n_{sig}+n_{bkg}} * sig(x) + \frac{n_{bkg}}{n_{sig}+n_{bkg}} * bkg(x)$$



Uncertainty propagation estimation method:

- Generate normal distribution random number N(0, 1.0);
- Deviate all shape parameters (k, μ, σ, a, A, B and C) from their mean values by their standard deviations multiplied by the random number of N(0, 1) at a time (operated by Eigen package, using the error matrix as input, which can generate dispersion table);
- Run the fitting N times (as you want) with the shape parameters of (fixed mean + random dispersion), but float the n_{sig} and n_{bkg}.
- The distribution of the n_{sig} and n_{bkg} be used to determine the signal/background yield dependence on the shapes.

Asymmetry Analysis – uncertainty propagation from the sig and bkg shapes



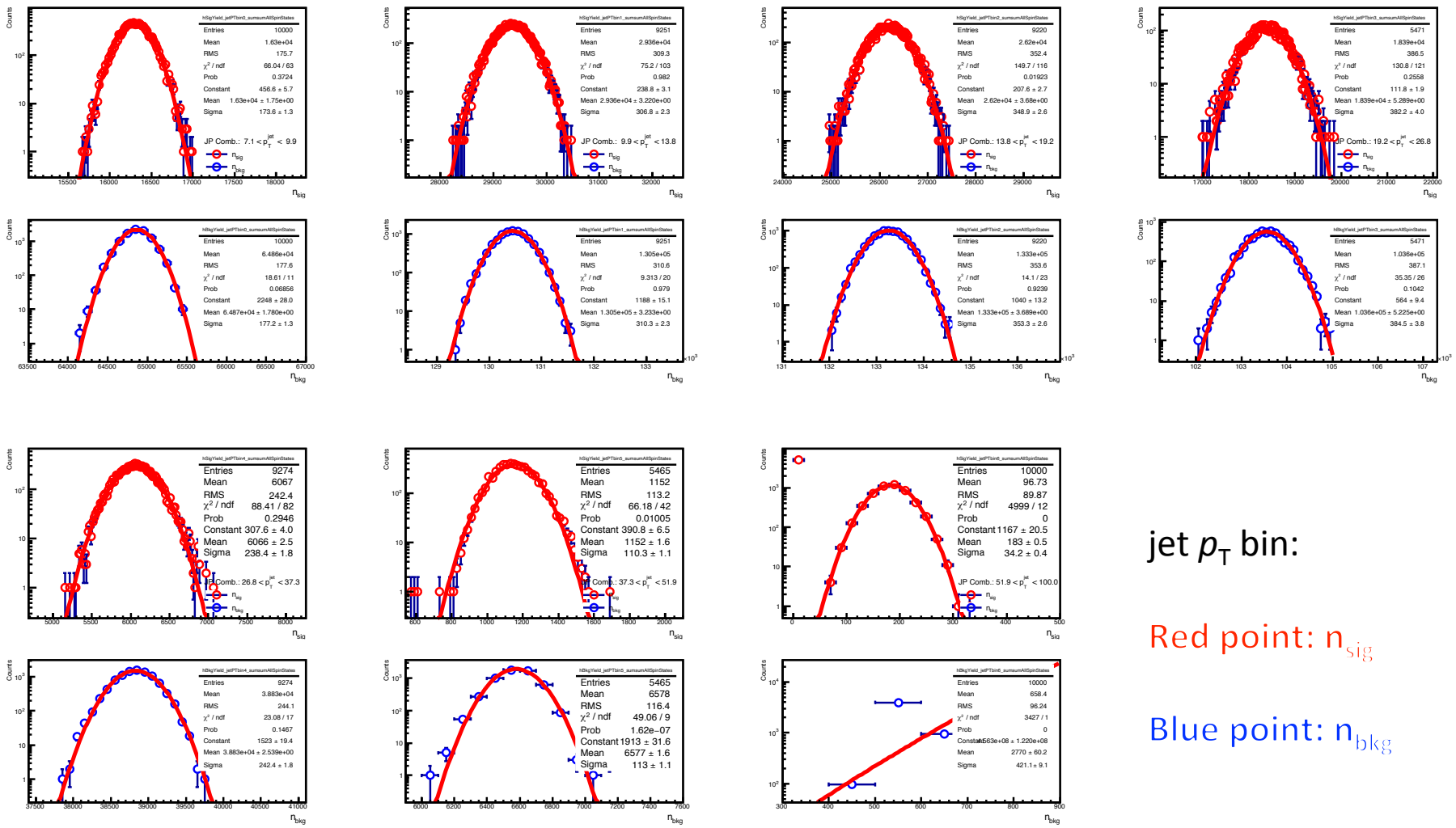
π^0 p_T bin:

Red point: n_{sig}

Blue point: n_{bkg}

π^0 p_T	[4.0, 5.0]	[5.0, 6.0]	[6.0, 8.0]	[8.0, 10.0]	[10.0, 12.0]	[12.0, 16.0]
Propagated uncertainty from shape (sig.)	1.1%	1.4%	1.5%	2.1%	3.2%	5.2%
Propagated uncertainty from shape (bkg.)	0.2%	0.3%	0.3%	0.6%	1.1%	2.6%

Asymmetry Analysis – uncertainty propagation from the sig and bkg shapes



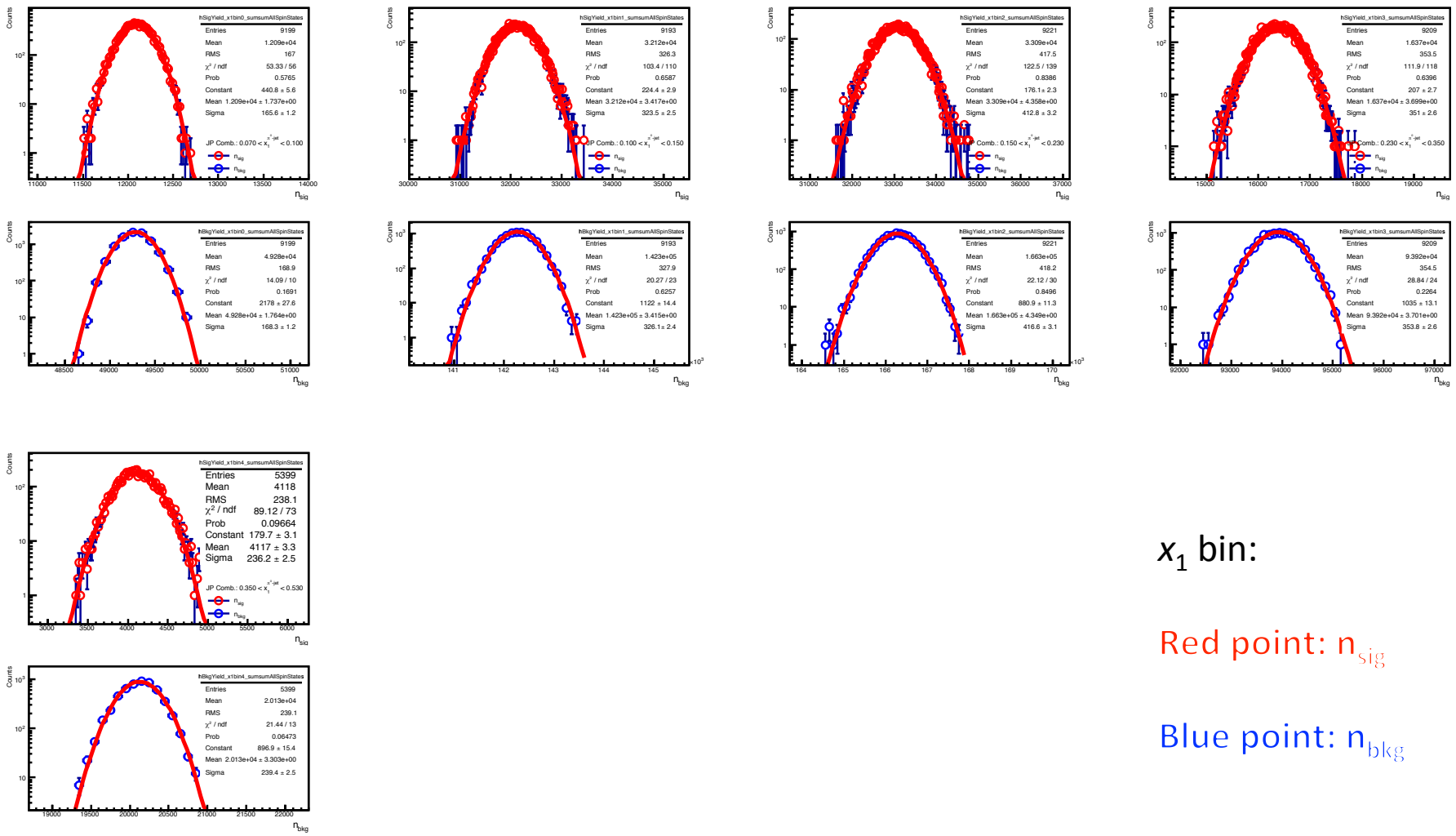
jet p_T bin:

Red point: n_{sig}

Blue point: n_{bkg}

jet p_T	[7.1, 9.9]	[9.9, 13.8]	[13.8, 19.2]	[19.2, 26.8]	[26.8, 37.3]	[37.3, 51.9]
Propagated uncertainty from shape (sig.)	1.1%	1.0%	1.3%	2.1%	3.9%	9.6%
Propagated uncertainty from shape (bkg.)	0.3%	0.2%	0.3%	0.4%	0.6%	1.7%

Asymmetry Analysis – uncertainty propagation from the sig and bkg shapes



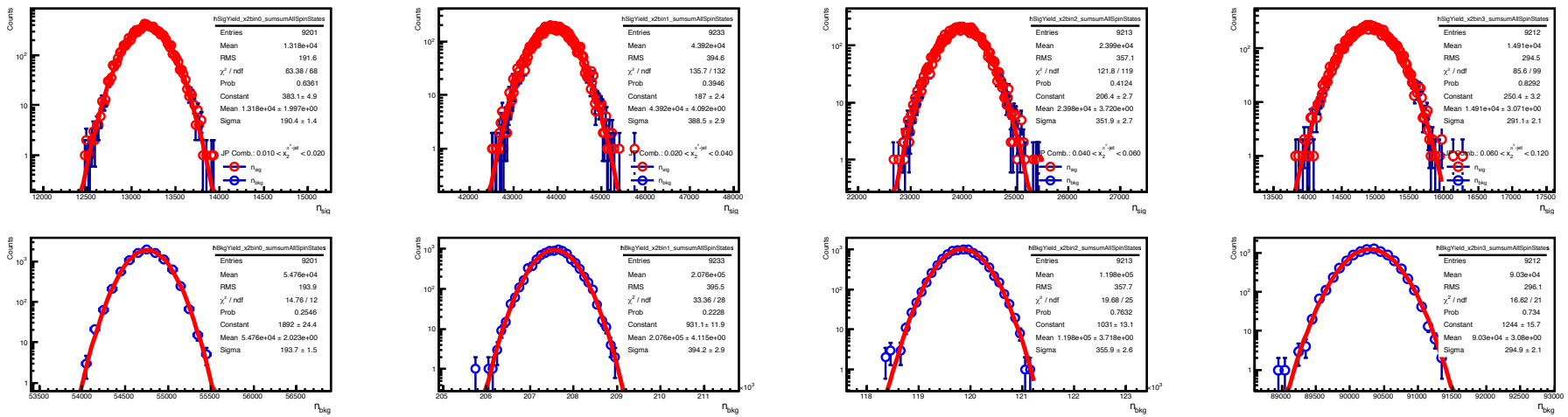
x_1 bin:

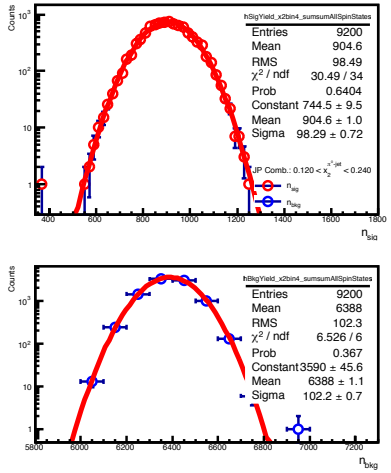
Red point: n_{sig}

Blue point: n_{bkg}

π^0-jet x_1	[0.07, 0.1]	[0.1, 0.15]	[0.15, 0.23]	[0.23, 0.35]	[0.35, 0.53]
Propagated uncertainty from shape (sig.)	1.4%	1.0%	1.2%	2.1%	5.7%
Propagated uncertainty from shape (bkg.)	0.3%	0.2%	0.3%	0.4%	1.2%

Asymmetry Analysis – uncertainty propagation from the sig and bkg shapes





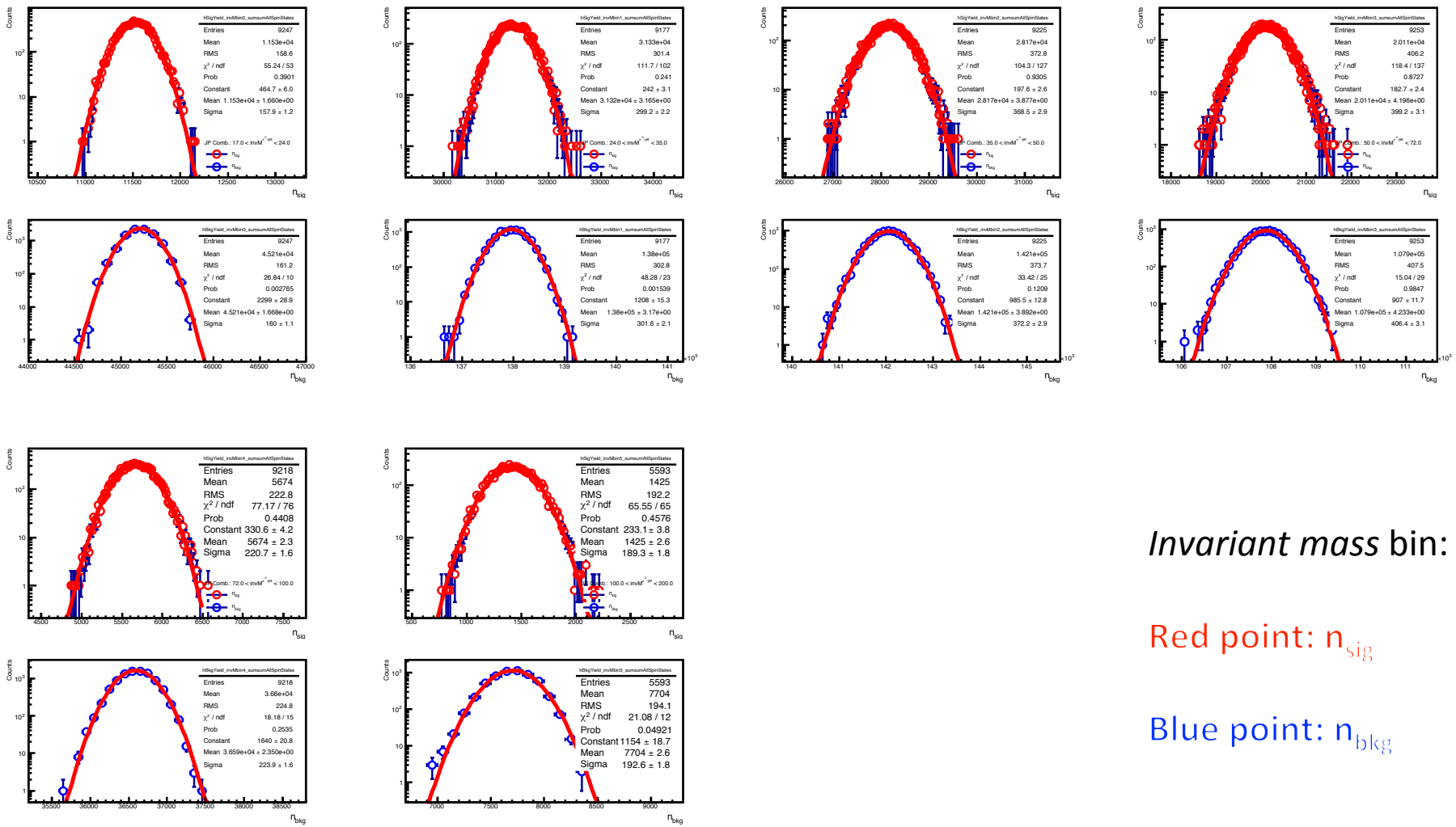
x_2 bin:

Red point: n_{sig}

Blue point: n_{bkg}

π^0-jet x_2	[0.01, 0.02]	[0.02, 0.04]	[0.04, 0.06]	[0.06, 0.12]	[0.12, 0.24]
Propagated uncertainty from shape (sig.)	1.4%	0.9%	1.5%	2.0%	10.9%
Propagated uncertainty from shape (bkg.)	0.35%	0.2%	0.3%	0.33%	1.6%

Asymmetry Analysis – uncertainty propagation from the sig and bkg shapes



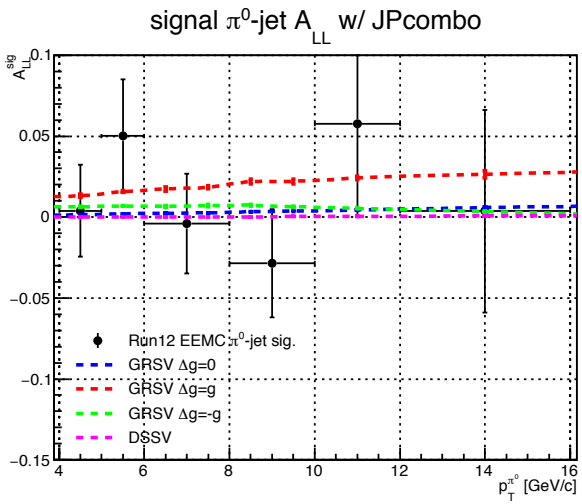
Invariant mass bin:

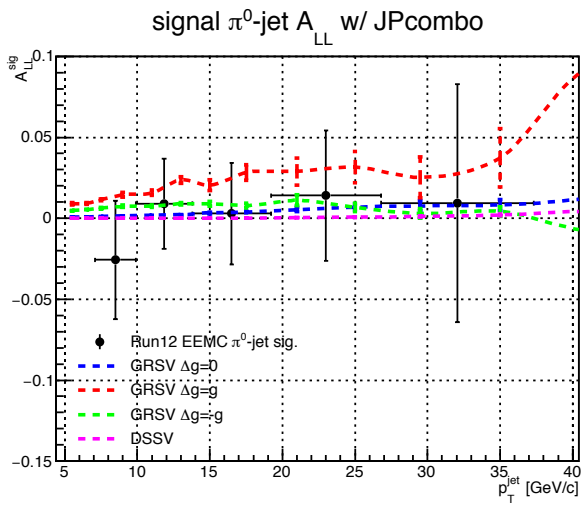
Red point: n_{sig}

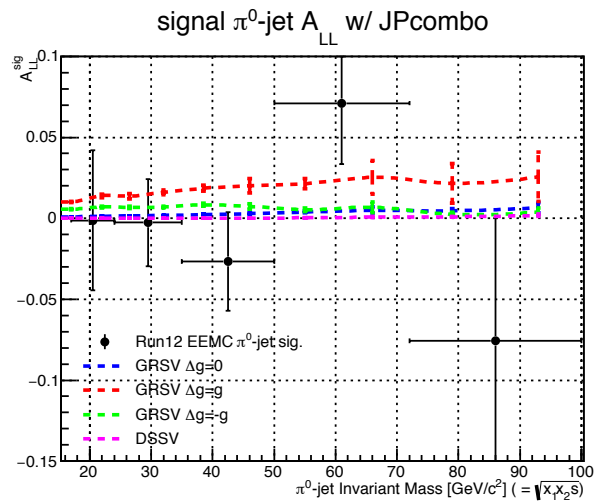
Blue point: n_{bkg}

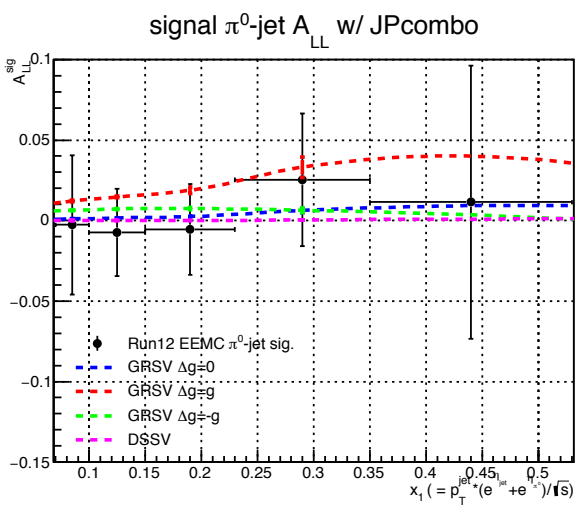
π^0-jet invM	[17, 24]	[24, 35]	[35, 50]	[50, 72]	[72, 100]	[100, 200]
Propagated uncertainty from shape (sig.)	1.4%	1.0%	1.3%	2.0%	3.9%	13.3%
Propagated uncertainty from shape (bkg.)	0.35%	0.22%	0.26%	0.38%	0.61%	2.5%

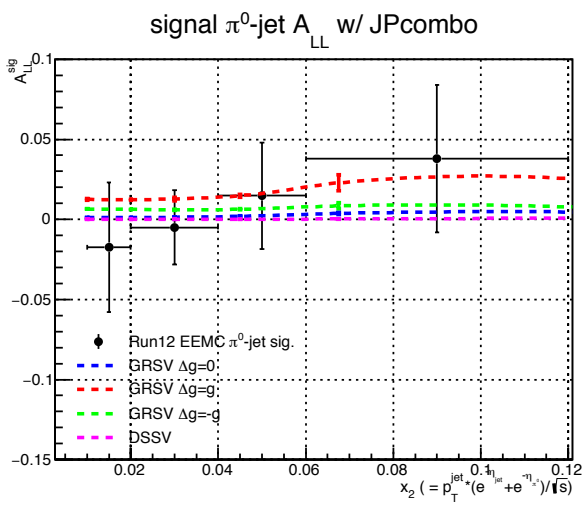
Asymmetry Results -- Updated longitudinal double asymmetry, A_{LL}



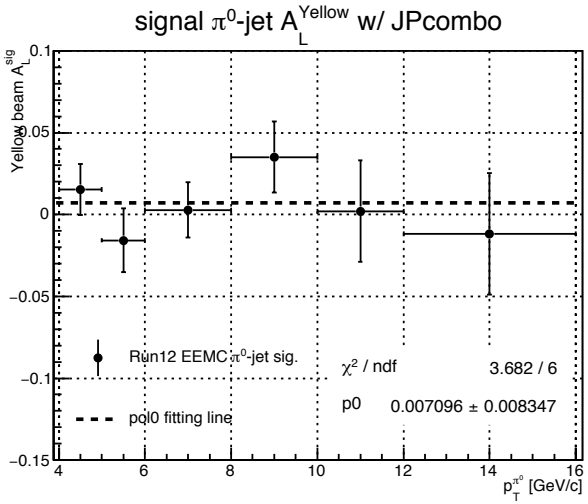


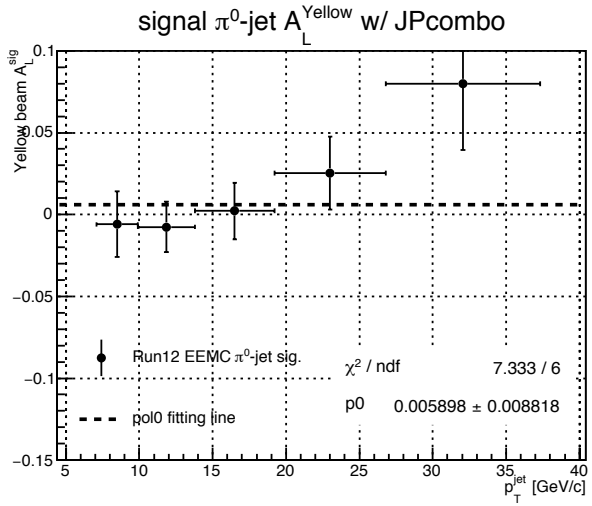


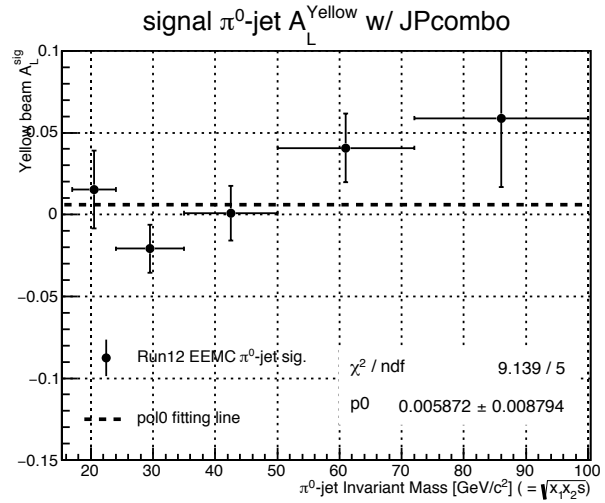


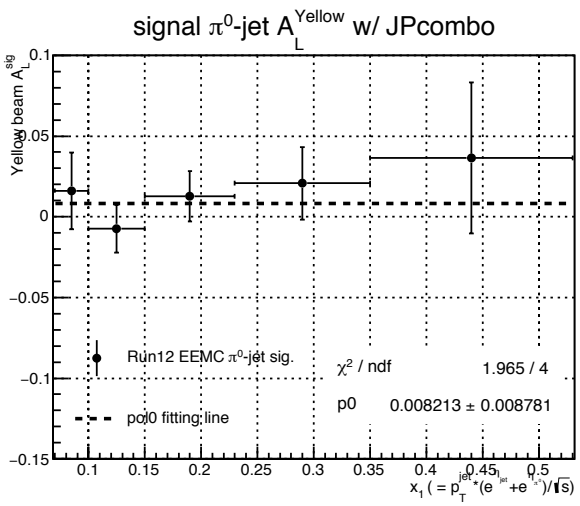


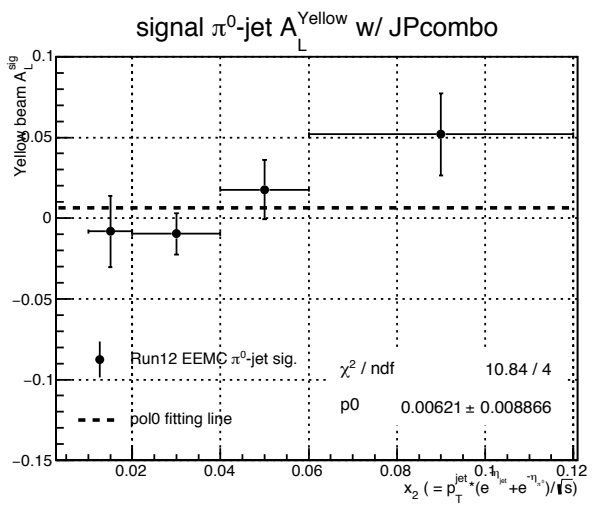
Asymmetry Results – Updated single asymmetries, A_L^Y



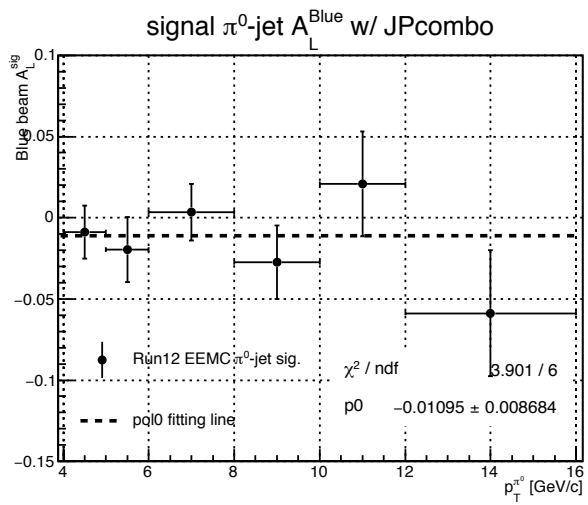


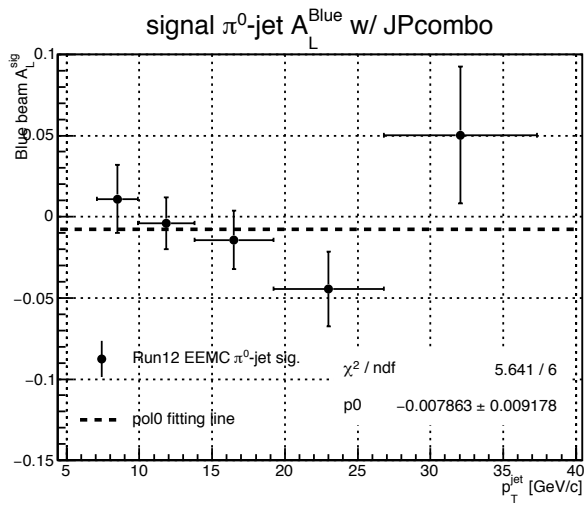


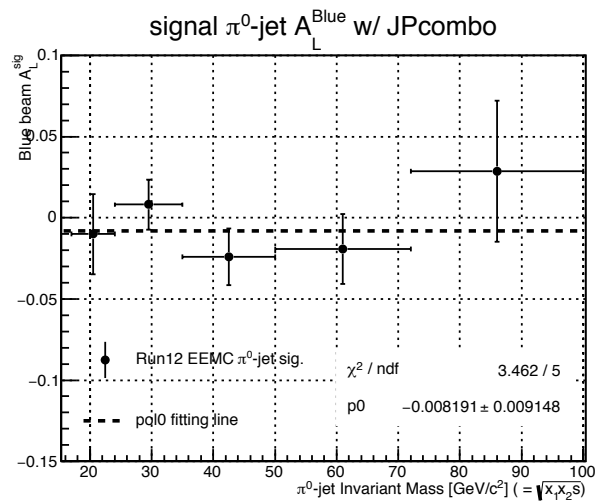


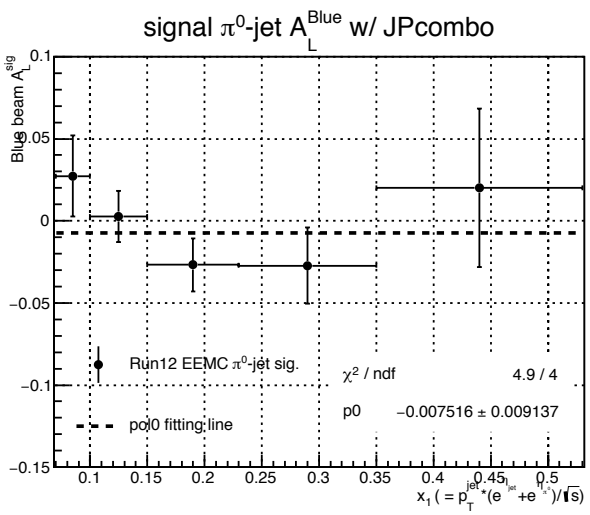


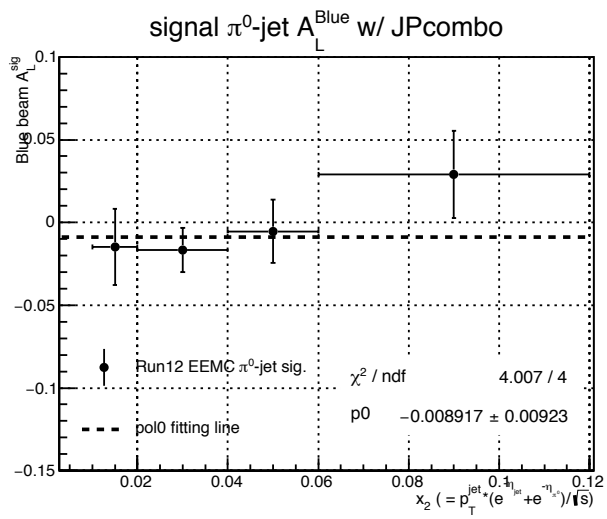
Asymmetry Results – Updated single asymmetries, A_L^B



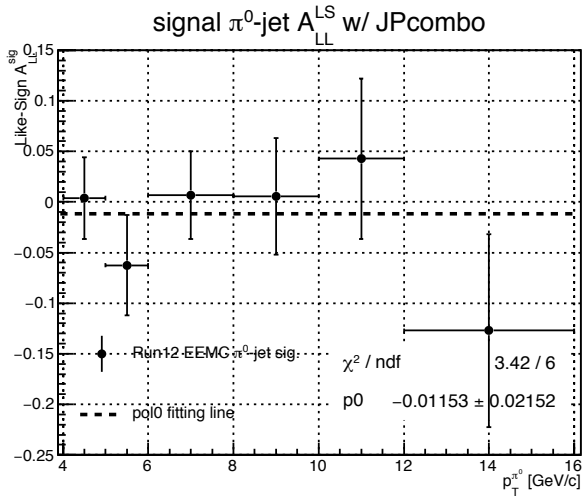


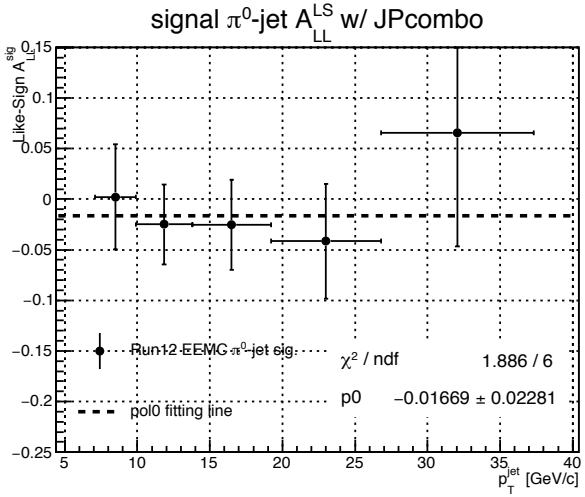


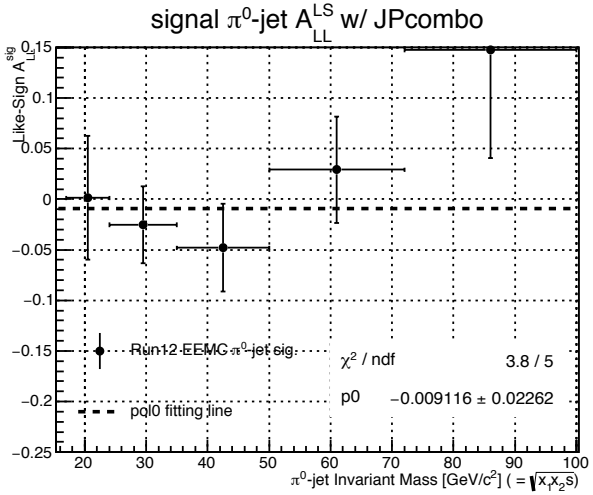


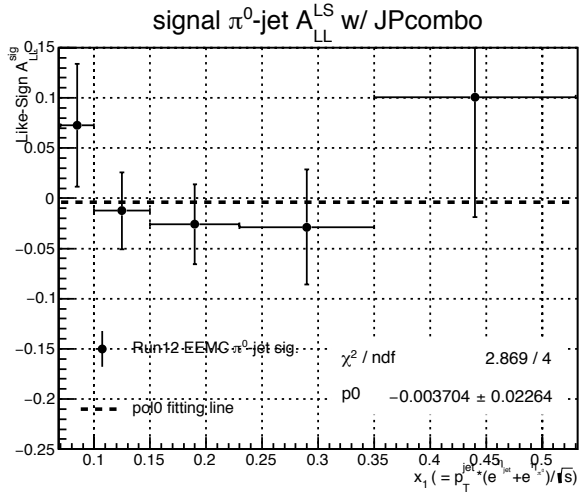


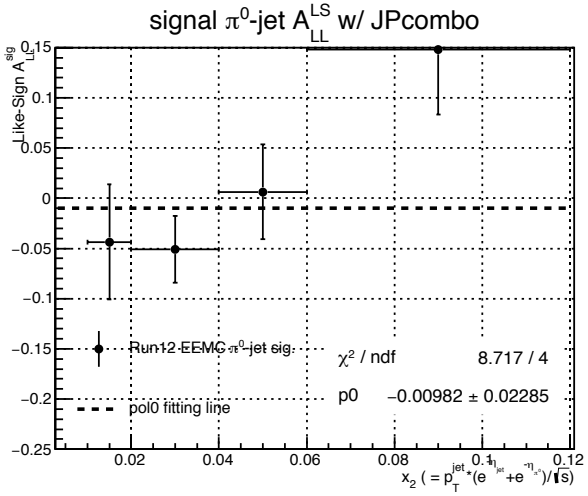
Asymmetry Results – Updated false asymmetries, A_{LL}^{LS}



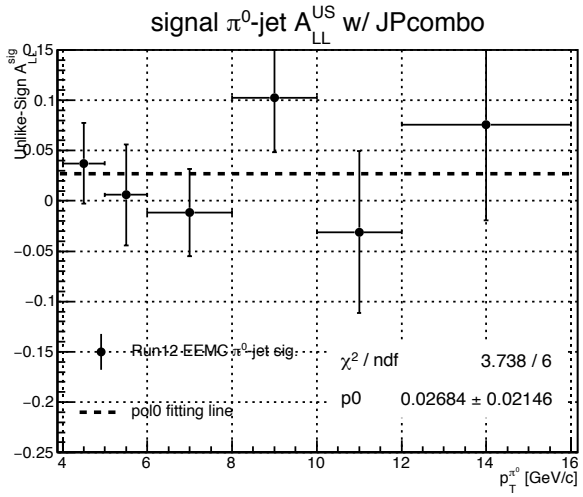


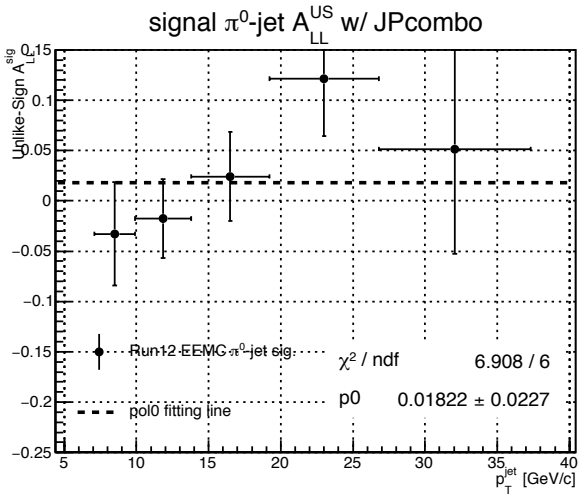


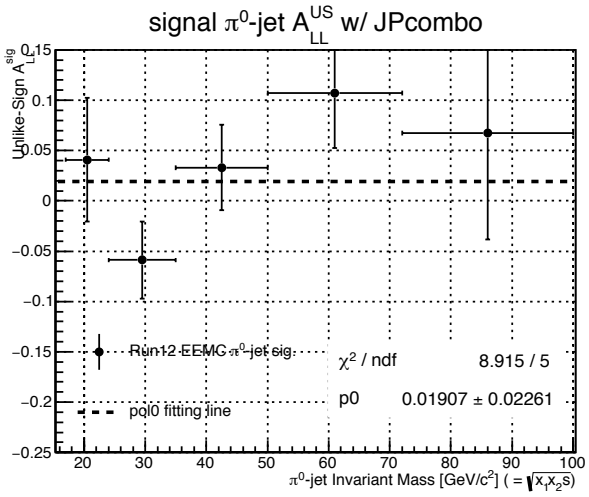


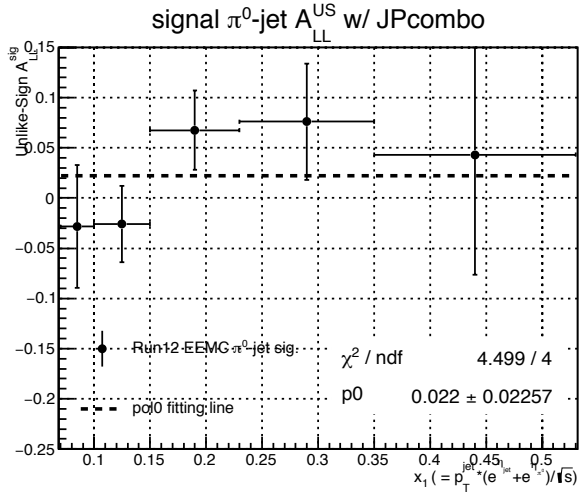


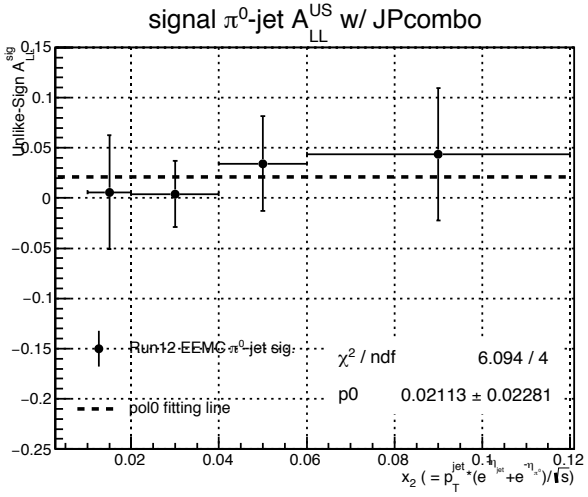
Asymmetry Results – Updated false asymmetries, A_{LL}^{US}











Summary and outlook

- According to the checks, the new method to extract signal looks reasonable/safe for A_{LL} calculations;
- Proposed a way to estimate the propagated uncertainties from the signal/ background shapes (in the new method), which will be included into the systematic uncertainties;
- Background false asymmetries look large, and need checks in coming weeks;
- Updated theoretical curves with latest PDFs will be available later.
- Re-estimate the systematic uncertainties.

- Target preliminary results for the coming SPIN2016.

Thanks for your attention!